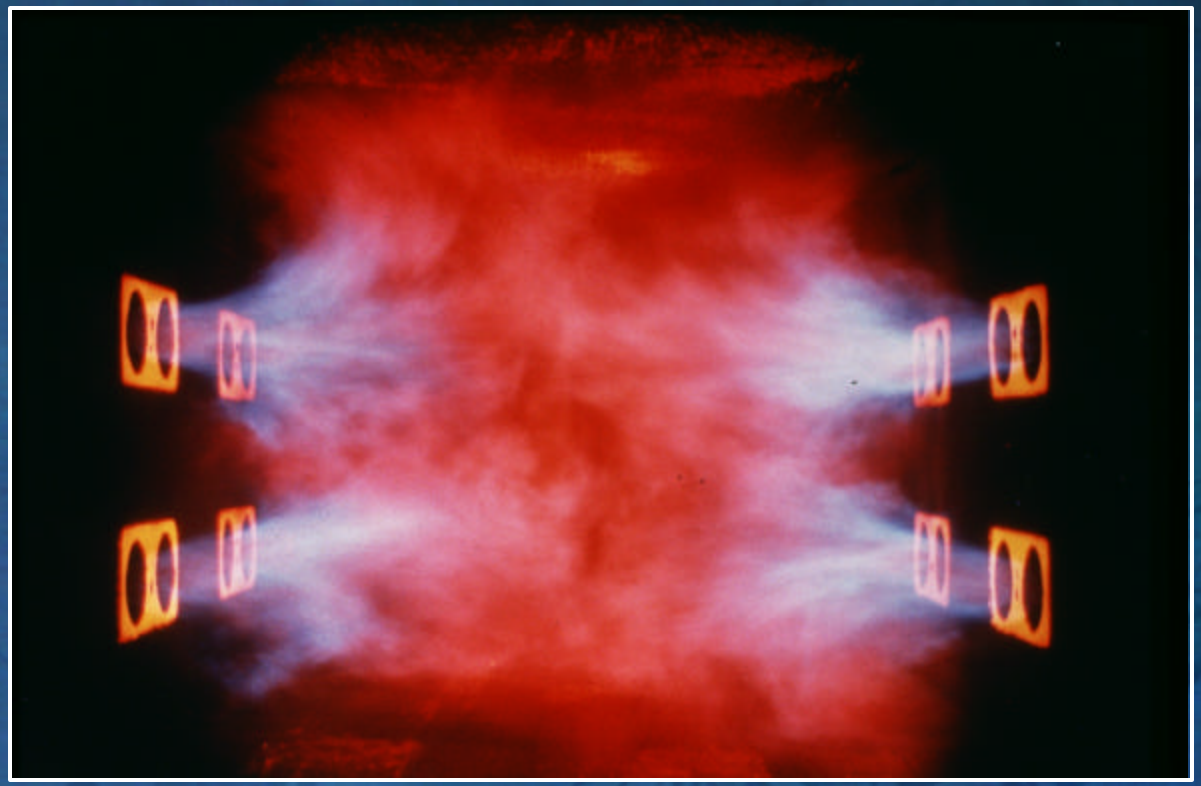
2002 Conference on SCR and NSCR for NOx Control

Advanced Combustion Technologies as an Alternative to Flue Gas Cleanup Systems for High Levels of NOx Reduction



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- Methods of NOx Formation - Gas Firing
- Typical NOx Reduction Methods
- Ultra Low NOx Burner
- Case Study
- Multiple Burner Boilers and Variable Fuels
- Case Study

Methods of NOx Formation - Gas Firing

Fuel NO_x from nitrogen contained in the fuel
- Typically not an issue on gas fuels

Thermal NOx from high temperature flame
- Typically 80 to 100% of NOx formed

Prompt NOx formed in fuel rich regions
- Up to 20% of NOx formed

Thermal NOx Reduction Methods

- Flue gas recirculation
  - Forced into Combustion Air (FFGR)
  - Induced into Combustion Air (IFGR)
  - Fuel Induced (FIR)
- Steam or water injection
- Fuel-air staging
  - Staged combustion burner designs
  - Furnace staging
    - Over fire air (OFA)
    - NOx ports
- Furnace Gas Entrainment

Prompt NOx Reduction Methods

- Eliminate Fuel Rich Regions
  - Pre-mix burners
  - Rapid mix burners
- Fuel Dilution
  - Fuel Induced Flue Gases (FIR)
  - Steam Injection

Ultra Low NOx Burners

- Ultra Low NOx burners for boiler applications have been available since the mid-1990's
- Operate with NOx levels of less than 9 ppm or 0.011 lb/mmbtu
- Combine Rapid Mixing for Prompt NOx reduction with IFGR for Thermal NOx control
- Well suited for single burners applications (packaged boilers)
- Not designed for fuels with varying composition (refinery gases)

Ultra Low NOx Burner Case Study

- 100,000 PPH D-type package boiler
- Natural gas fired
- Ambient combustion air
- Existing Low NOx burner replaced with Ultra Low NOx burner (higher capacity)
- New combustion air fan sized for 30% IFGR
- NOx less than 8.5 ppm across entire load range
- CO less than 1 ppm across entire load range
- Boiler capacity increased to 110,000 lb/hr

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Multiple Burner Boilers and Variable Fuels

- Multiple burner boilers represent a wide range of furnace configurations
- In many cases the impact on existing system components must be worked around (fans, air heaters, superheaters)
- Changes in fuel composition require NOx reduction technologies that have the flexibility to compensate
- NOx reduction in these cases becomes a custom engineered solution rather than an “off the shelf” product
- This typically involves combining several different technologies to get the greatest reduction at the lowest cost and impact to the system

NOx Reduction System Case Study

- Five existing field erected boilers
  - Four Riley 140,000 PPH (1936 - 1941 vintage)
  - One B & W 180,000 PPH (1953 vintage)
- Existing OEM register type burners
  - Four burners per Riley boiler
  - Five burners on the B & W boiler
- Preheated combustion air of 440 - 650 deg F
- Refinery gas fuel with 25 - 40% H2 content
- Baseline NOx levels ranged from 250 to 450 ppm
- New BAAQMD regulations required NOx to be reduced to less than 27 ppm
- 90 to 94% NOx reduction required

The Initial Solution

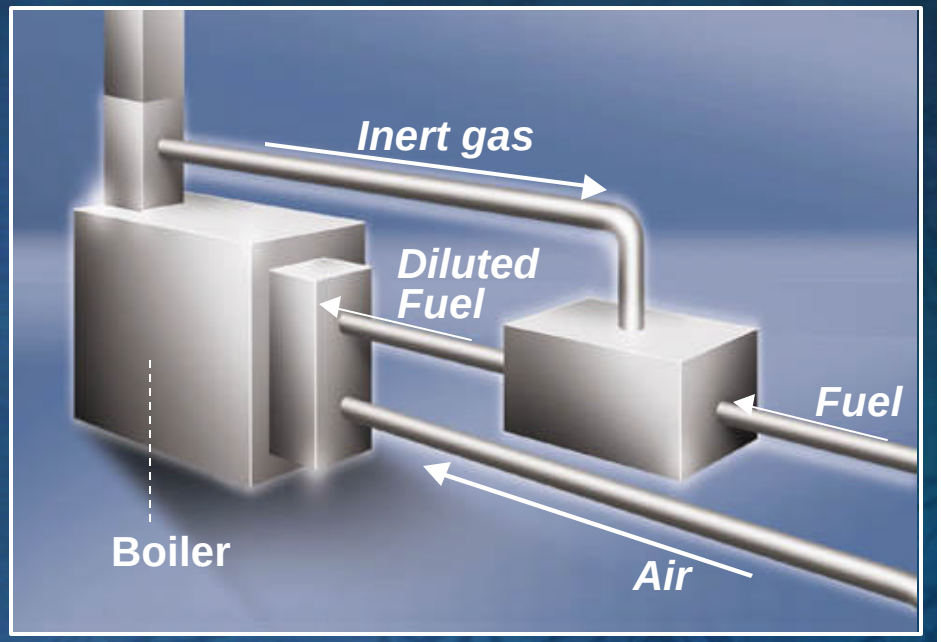
- Two SCR systems located behind the boiler house
- 2,500 HP fan and complicated ducting to deliver the flue gas to the SCR's
- Earth moving of the large hill behind the boiler house
- Over $20 million capital cost for the project
- Increased operating cost of $1 - $1.5 million per year

Looking at Alternatives

- High cost of the project made it worth while for the NOx Reduction Team to look at other alternatives
- One spare boiler was available for testing and demonstration
- They decided to conduct a co-operative development program involving the engineering company, combustion consultant, and burner manufacturer
- Prototype burners were installed to test the feasibility of a combustion solution
- The successful test led to the retrofit of all five boilers

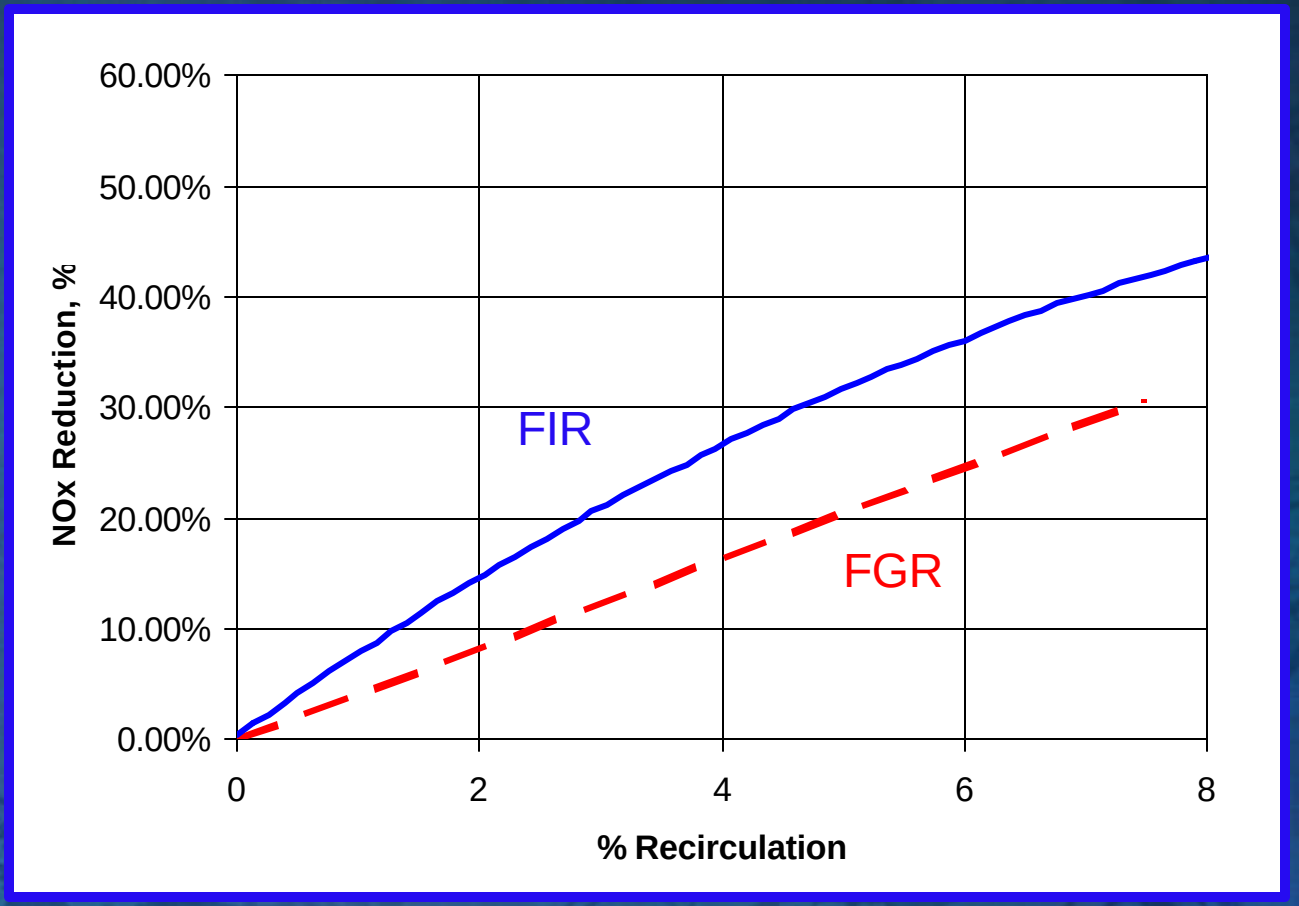
Combustion Technologies

- New burners incorporating several NOx reduction techniques
- Fuel Dilution
  - Introduction of flue gases into the fuel
  - Lowers the heating value of the fuel
  - The diluted fuel results in lower NOx
- Steam Injection
  - Serves as an additional diluent
  - Induces additional amounts of flue gas
- Induced Flue Gas Recirculation (IFGR)



Fuel Dilution

- Affects both Thermal and Prompt NOx formation
- Therefore adding the flue gases to the fuel has a greater effect on NOx reduction than adding them to the combustion air

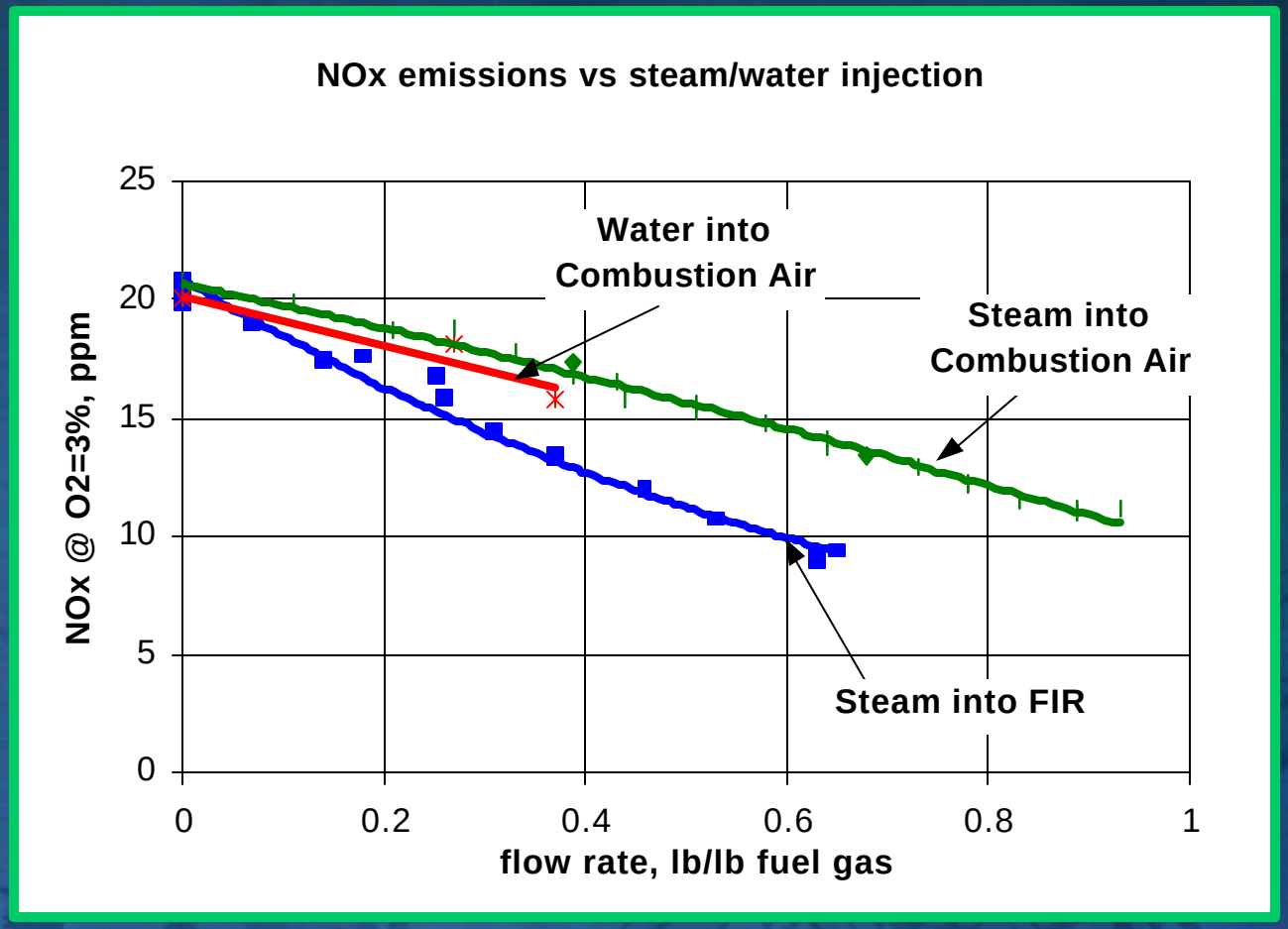


John Zink LCF Burner

- Incorporates fuel dilution built into the burner
- Fuel pressure is the motive force to draw in the flue gas
- No additional fan horsepower required to transport flue gases to burner
- Reduces NOx by > 80%

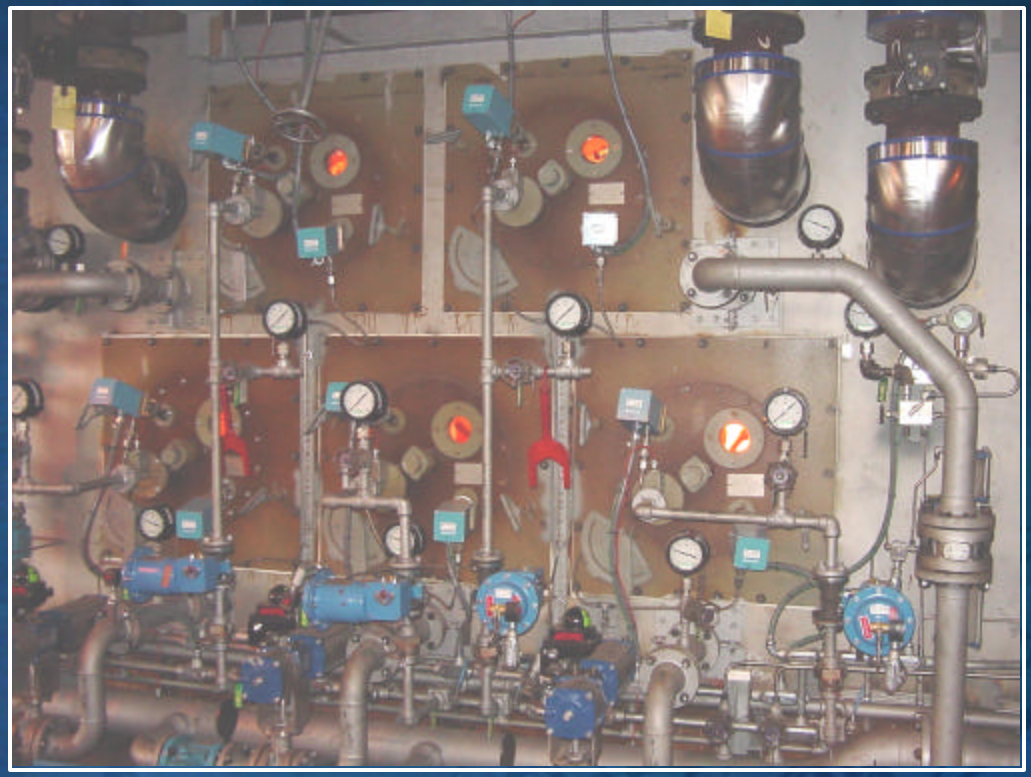
Injection of Steam for NOx Reduction

- Steam used to get the remaining NOx reduction required
- Effectiveness of steam dependant on method of injection
- Mixing it into the fuel gives the biggest NOx reduction
- Minimizing steam usage minimizes operating cost impacts



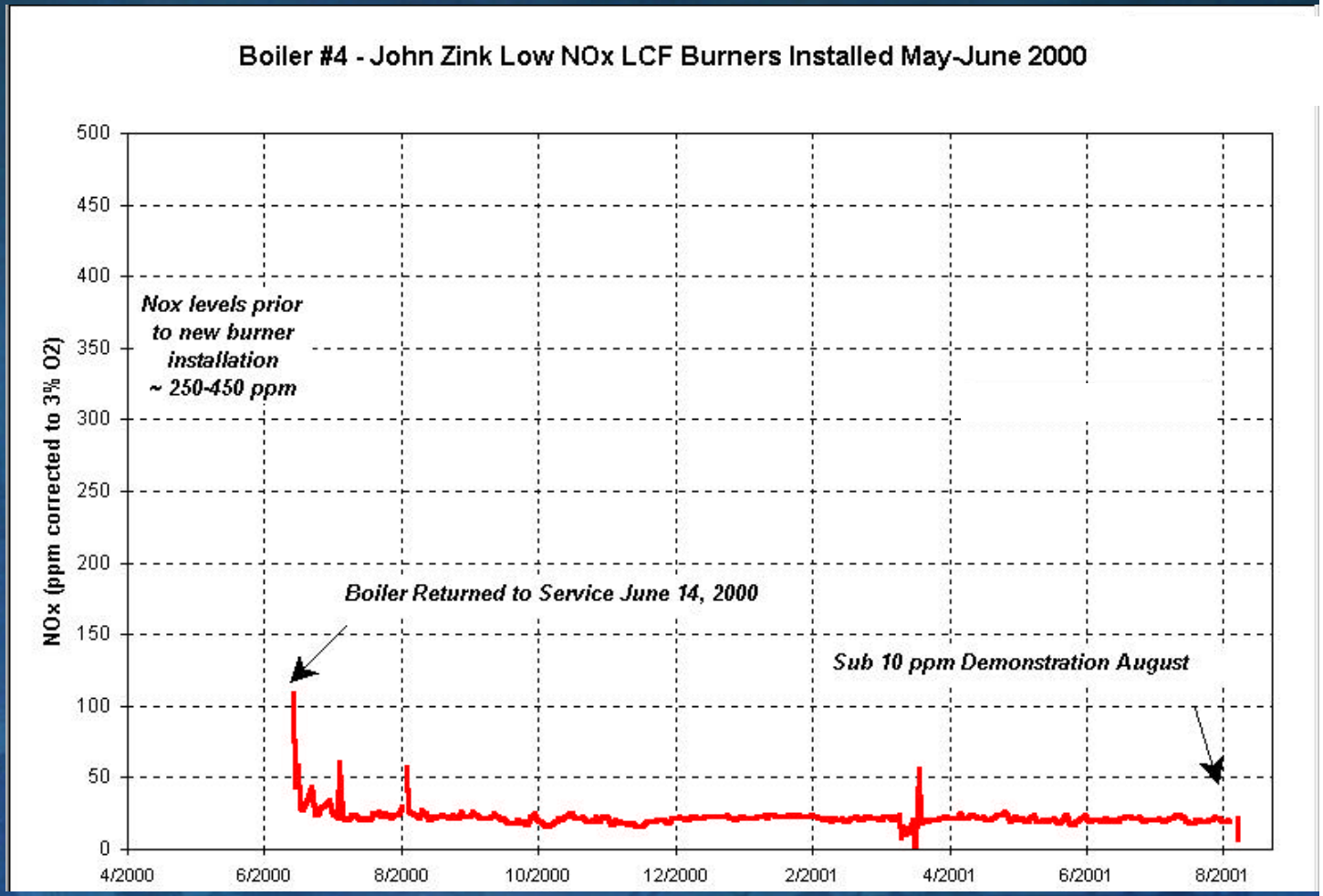
The Installation

- All five boilers retrofitted with new burners
- New LCF burners with fuel dilution reduced the NOx to less than 70 ppm (~83% reduction)
- Addition of steam injection reduced NOx to less than 24 ppm (~94% reduction)
- Induced 2-3% FGR reduced NOx to less than 22 ppm (~95% reduction)



Continued Reliable Operation

- Over 20 months of continued operation at less than 25 ppm NOx
- No reduction of load capability
- Excellent ability to handle load swings
- No problems with varying refinery fuel composition



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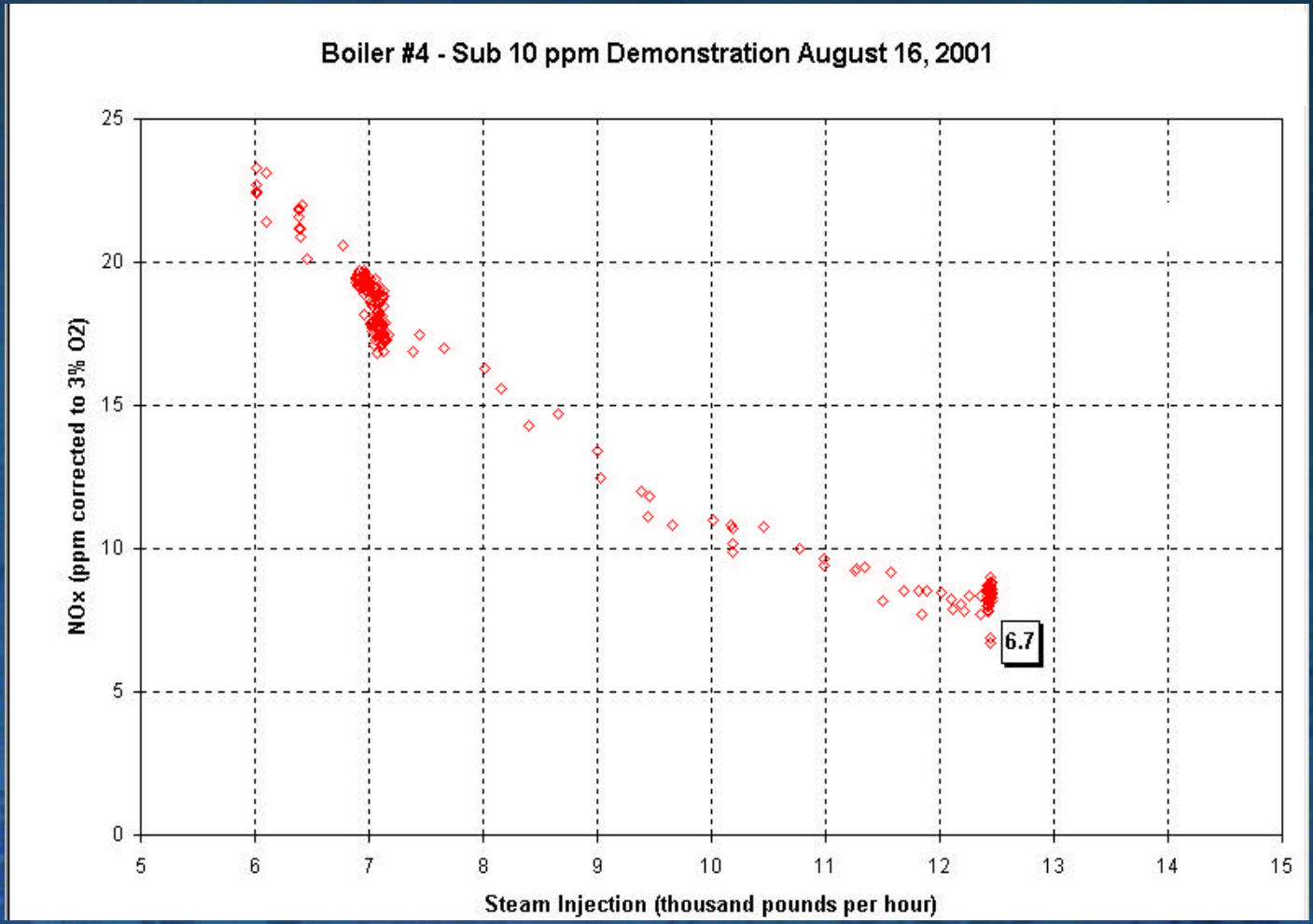
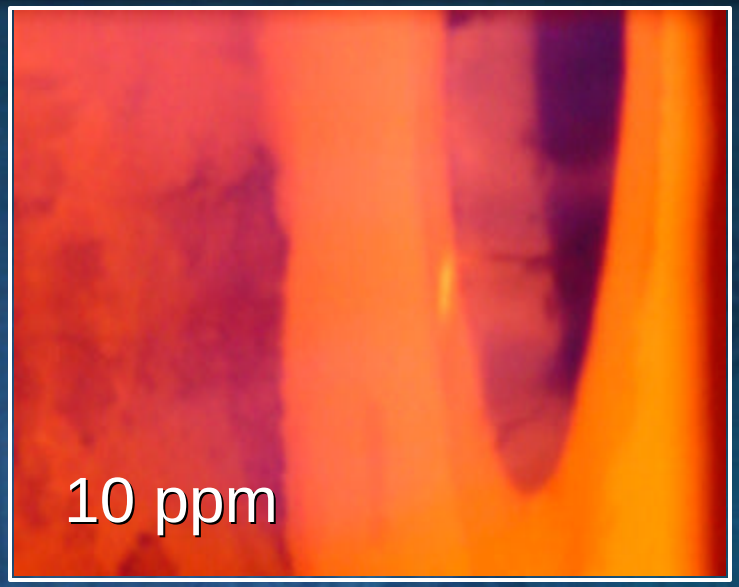
How Low Can We Go?

- Testing conducted to see how low NOx could be reduced with increased steam flow
- NOx level of less than 7 ppm was achieved with maximum steam flow



Flame Appearance at Ultra Low NOx Levels



Project Results

- Exceeded NOx reduction target and all boilers now operate in compliance with new limit (CEM)
- Saved over $7 million on the cost of the project
- Eliminated increased operating cost of $1 - $1.5 million per year
- Demonstrated ability to reduce NOx down to less than 7 ppm if ever required

Summary

- NOx reductions of over 90% are achievable on gas fired boilers
- Combustion based solutions are more economical than flue gas cleanup
- Boiler design and configuration play a large part in determining the best solution
- Fuel and operating requirements must be taken into account in the system design

Developing Clean Air Solutions for Planet Earth

TODD® Combustion

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